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Consider the Sea Breeze when Evaluating Offshore Wind Resources

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Introduction

In view of the current proposal by LIPA to build a significant wind turbine farm off the South coast of Long Island, the following discussion of the added value of the Sea Breeze to the economics of that venture needs to be considered. *The coincidence of a dependable daily wind phenomenon in that region with the extreme cost of power in the region during the peak load periods of hot summer afternoons makes a significant contribution to the economic and social values of the proposed wind energy system.* This will be illustrated using a brief period in the summer of 1999, taken from a study performed at that time by the author in support of a proposal to LIPA for a proprietary wind turbine system. Based on the study for the summer of 1999, the estimated value of the sea breeze effect is about 30% of the annual value of wind energy in this region. This implies that this effect must be considered as a reason not to locate the wind turbines any farther from the shore than necessary, because the sea breeze diminishes with distance from the shoreline.

Background

The Sea Breeze as a Peak-Shaving Resource – The Sea Breeze is a recurring local summer weather phenomenon that is caused by the rising of heated air over a coastal land mass, requiring that cooler air from the neighboring body of water rush in to take its place. On Long Island's South Shore, this is a particularly dependable phenomenon in the hot months of June, July, August and September; deterred only by heavy overcast or a strong northerly flow from the current weather system in the region. Figure 1 shows a typical summer afternoon wind pattern as

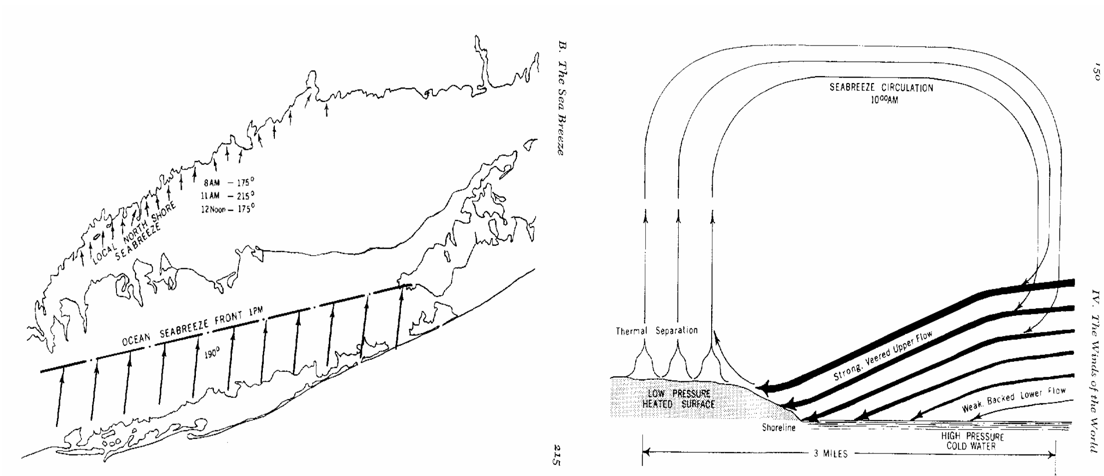

Figure 1 – The Characteristics of the Long Island Sea Breeze
(from Walker, Stuart; Wind and Strategy, Norton, NY 1973

it evolves across the island in a northerly direction. Figure 1 also shows the early onset of the sea breeze along the South Shore, and gives a mechanistic image of its vertical circulation structure. Along the Barrier Reef (Rockaway's, Jones Beach, Fire Island, Westhampton Beach) the typical onset is 10:00 am, and the breeze will probably last until sunset. The strength of the wind will vary with many factors, but often reaches 22 MPH. *The fundamental premise of this discussion is that the sea breeze coincides with the period of peak electrical demand on Long Island.* This premise is sound because the high temperatures that drive the sea breeze create the air conditioning demand further inland. The factors that inhibit the sea breeze (NW flow behind a cold front, overcast, rain, Northeast or Easterly flow) also relieve the need for air conditioning. Because each marginal kilowatt at peak load has a disproportionate value to the responsible utility, the wind turbine (WT) array would be built primarily to add power to the grid at these stressing times. The WT's would contribute power at any time that there was local wind, but we expect that the aggregate wholesale value of that "business-as-usual" generation would be comparable to the value contributed in a small number of hours during high-load summer afternoons. The utility must pay a very large premium for power at these times, and distribute it over cables that are already overloaded. Figure 2 shows the first correlation of summer data that convolves the local utility's cost of power with the wind resource at a representative site for each hour of the day over a significant portion of the current summer.

One important comment about the sea breeze that bears on the siting of wind turbines, particularly the distance offshore, is that the sea breeze is known to diminish with distance from the shore. Estimates vary, but most observers agree that the sea breeze effect is significantly reduced by 5 miles from the shoreline.

Analysis

Figure 2 shows the first result of the prediction of the hour-by hour value of wind power density at the South Shore. We have chosen to base all results in this study on a wind turbine power coefficient (C_p) of unity, whereas all actual wind turbine power coefficients will be less than

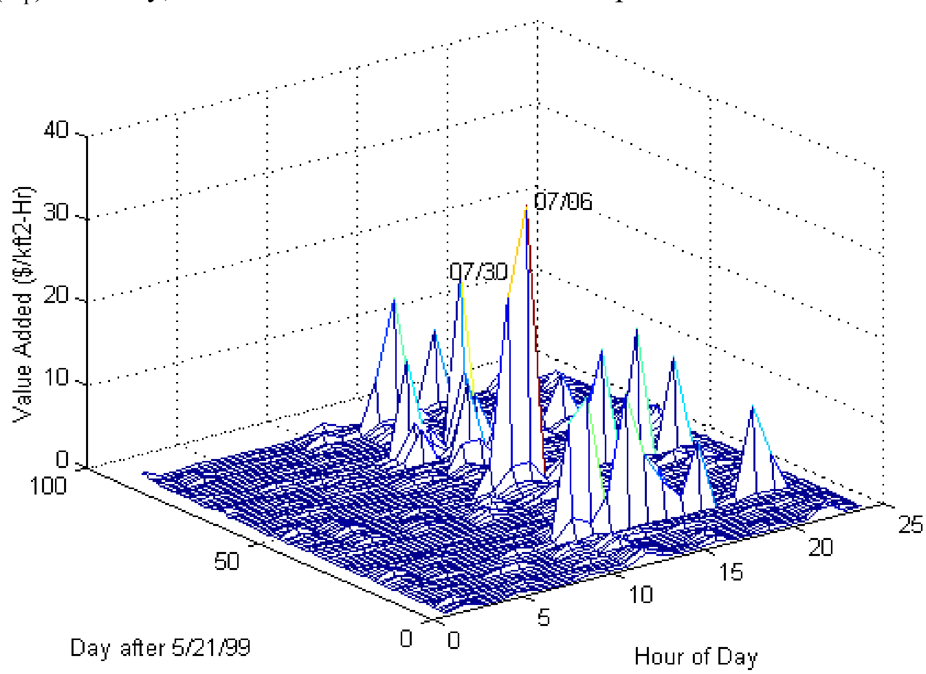

Figure 2 – Time-Resolved Value of WT Output for 89 Days, Summer 1999. $C_p = 1.0$

about 0.4. All actual costs and values will be proportional to the actual C_p. Note that on particular days the contribution in the afternoon becomes disproportionately high. We have identified the notorious 6^{th} of July 1999 (the first day of extreme brownouts that year), and the 30^{th} of July as prime examples in Figure 2. This demonstrates our main premise that the correlation between the timing of the sea breeze and that of the electrical cost peaks contributes significant extra value. In actual practice, the real value of the turbines will probably be mostly in their relief of local distribution networks and reduction of outages, rather than in the dollar value of their power. There is also an environmental and cultural value in pioneering in the generation of clean, renewable energy. Details of the calculation of the value of the WT electricity and its synchronicity with the wind energy are given in the Appendix.

Figure 3 shows the average over all days in the 89-day period of the cash value of the power that a wind turbine with unit Power Coefficient (Cp= 1) could have produced in every hour. *This is where we show the value of the sea breeze most clearly*. Note that the summer winds are generally poor except for the afternoon sea breeze. Because the cost (i.e., value) of power is similarly timed, the sea breeze is responsible for most of the value contributed by the WT array from mid-May until October. Since we have used a nearby hub as the basis for the value of power, there is also a transmission cost, and often congestion cost at the times of sea breeze. In calculating income from WT's from the data of Figures 2 & 3, we have chosen to escalate the LMP by 10% for transmission at all times, and the LMP in the sea-breeze season by an additional 20% for congestion. (See Appendix) These figures are consistent with PJM and New England SIO data, and we believe them to be conservative.

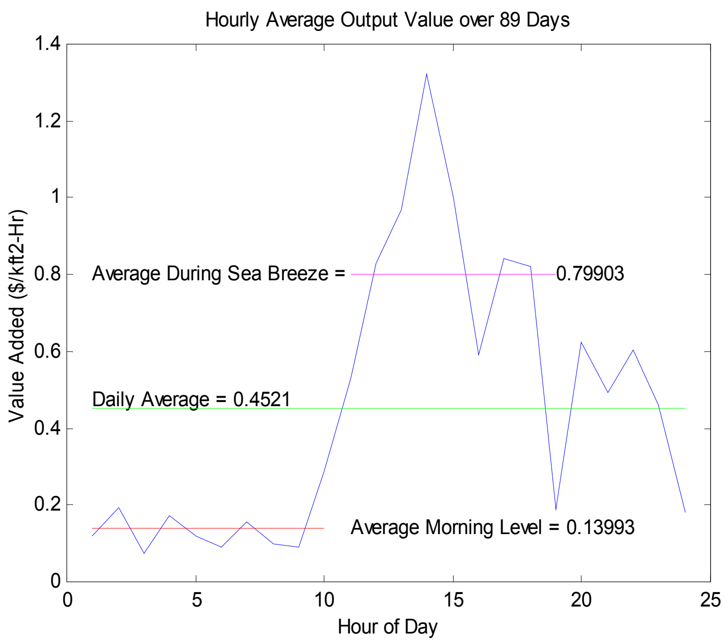

Figure 3 - Value of Power Available during May 22 through Aug 28, 1999 at JFK; C_p= 1.0

(Actual wind turbine C_p will be less than 0.5)

As shown in the Appendix, our analysis indicates that in the summer of 1999, the sea breeze effect, including the premium value of electrical energy at the times that the sea breeze prevails, is approximately 30% of the annual value of wind energy for these proposed offshore installations. This is too significant a value to be ignored.

Appendix

Analysis of Wind Energy Coincidence with Power Cost

In order to estimate the value added by a system of wind turbines along the shore, we must consider the correlation between recurring wind patterns and recurring power demand structures. While the sea breeze stands out in this respect, there are also strong season patterns in both energy cost (due to demand) and wind patterns. Through the sea breeze period, these fluctuations must be considered individually for every hour of the sea breeze season, whereas the value of the energy produced the rest of the year can be estimated by monthly averages of each factor. We have taken the from the PJM Independent Service Operator's (Eastern Hub) web site (www.pjm.com)*, which has accumulated cost data hourly on the Locational Marginal Price (LMP, $/MWh) by location and time of day for every recent day. This is our best approximation to the price at which LIPA can purchase power from the local grid. NY State's version of PJM is still not active with real cost data, although it does publish some simulations for the LIPA region. Hopefully those local real data will be available soon. The alternative active site (www.iso-ne.com) for New England's Power Pool presents its data in a form that is prohibitive for

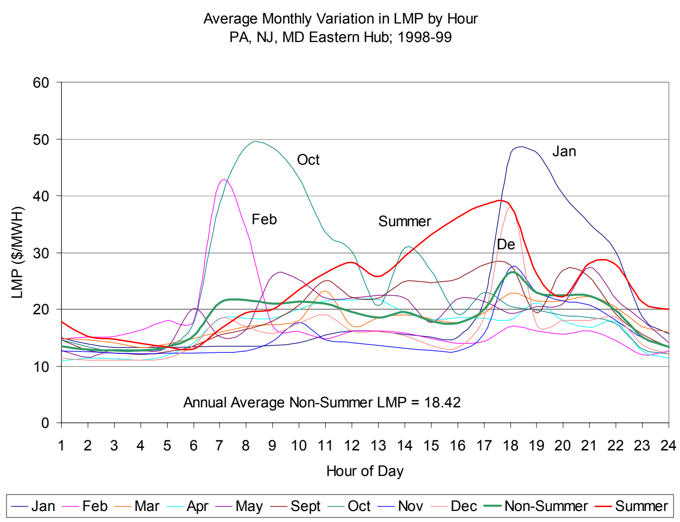

Figure A-1 – PJM Marginal Cost of Power by Month

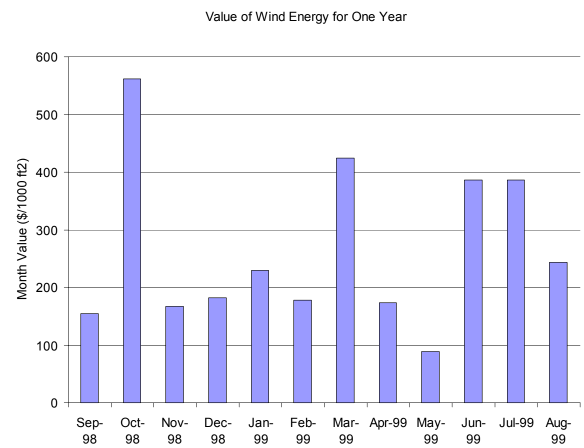

Figure A-2 – Value of Wind Power by Month C_p= 1

downloading and processing the 2160 data points we need for an 89-day study. We chose wind velocity data from the most prolific location available for proximity to the sea breeze phenomenon, JFK Airport (www.uswx.com/wx/us/NY/NY078, Location symbol KJFK). These data were reformatted and shifted to synchronize with the power cost data. (The wind velocity data are in GMT, 5 hours greater than the power times.) The wind velocity was converted to ft/sec units, cubed, and multiplied by ½ ρ to get the Wind Energy Density in watts/1000 sq ft – hr. The wind energy density is then multiplied (element by element) by the LMP for the same hourly period, and the value of the power produced per hour is plotted in Figure 2 (main text). Note that these calculations are not weighted in the same way as a utility's cost would be. For a

* Some of the URL's employed in the original study may no longer be active or contain the data employed in the study.

utility, the cost of satisfying the load is the power demand times the cost per MWH. For the WT, it is the amount available from the WT array times the cost per marginal MWH. For the wind resource assessment, the proper hourly value to average across a month is the wind power density (MWatts/1000ft^2), which is proportional to the 3rd power of the velocity. Figure A-1 shows the actual data on the cost of marginal power in the NY Bight through the past 12 months. Figure A-2 shows how this monthly value of power convolves with the monthly wind power densities to produce monthly and annual values of 1000 ft^2 of WT's operating at unit power coefficient. Note that the annual wind power density for our data is 181 W/m^2 is a little lower than the rating of the annual wind resource at Long Island's South Shore (rated Class 4 by the DoE's Wind Energy Resource Atlas of the United States http://rredc.nrel.gov/wind/pubs/atlas). Class 4 yields an annual average of from 200 to 250 w/m^2 at a mean height of 33 ft, and the real wind data we have used totals 181 W/m^2. This implies that we have somewhat underestimated the recurring annual wind resource in the detailed approach covered above.

A rough estimate of the incremental value of the sea breeze can be made by assuming that in the absence of the sea breeze and its concomitant electrical cost premium the wind power values for June, July, August and September would be approximately equal to that for May. In 1999 the corresponding "excess" values so defined would be as shown in Table A-1, giving an estimated value of the sea breeze effect in that year of 30.7 % of the total annual wind energy value.

Table A-1 – 1999 Value of Wind Energy @ Cp=1

	Wind Energy Value @ Cp=1	10%	20%	Estimated Sea breeze value
	$/1000ft2/yr	Transmission	Congestion	
Jan-99	$229.83	$252.81	$252.81	$0.00
Feb-99	$177.79	$195.57	$195.57	$0.00
Mar-99	$424.63	$467.10	$467.10	$0.00
Apr-99	$173.13	$190.45	$190.45	$0.00
May-99	$88.86	$97.74	$97.74	$0.00
Jun-99	$386.40	$425.04	$510.05	$412.30
Jul-99	$386.40	$425.04	$510.05	$412.30
Aug-99	$243.17	$267.49	$320.99	$223.24
Sep-98	$153.99	$169.39	$203.27	$105.53
Oct-98	$562.29	$618.52	$618.52	$0.00
Nov-98	$167.59	$184.35	$184.35	$0.00
Dec-98	$182.12	$200.33	$200.33	$0.00
	$3,176.21	$3,493.83	$3,751.23	$1,153.38
				30.7%